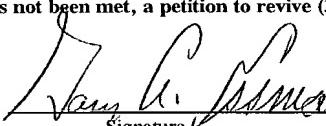
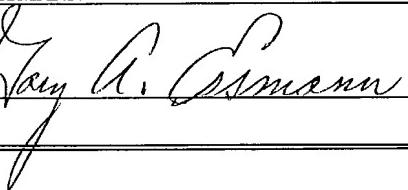


JC10 Rec'd PCT/PTO 15 FEB 2002

FORM PTO 1390 (REV. 11-2000)	U S DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE <b>TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371</b>	ATTORNEY DOCKET NUMBER 825-161
		U S. APPLICATION NO. (if known, see 37 CFR 1.5) <b>10/049690</b>

INTERNATIONAL APPLICATION NO. PCT/EP00/08084	INTERNATIONAL FILING DATE 08/18/2000	PRIORITY DATE CLAIMED 08/18/1999
TITLE OF INVENTION AXIAL PISTON DRIVE WITH A CONTINUOUSLY ADJUSTABLE PISTON STROKE		
APPLICANT(S) FOR DO/EO/US THOMAS DIEDEMANN and OTFRIED SCHWARZKOPF		
Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:		
<ol style="list-style-type: none"><li>1. <input checked="" type="checkbox"/> This is a <b>FIRST</b> submission of items concerning a filing under 35 U.S.C. 371.</li><li>2. <input type="checkbox"/> This is a <b>SECOND</b> or <b>SUBSEQUENT</b> submission of items concerning a filing under 35 U.S.C. 371.</li><li>3. <input type="checkbox"/> This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (21) indicated below.</li><li>4. <input type="checkbox"/> The US has been elected by the expiration of 19 months from the priority date (Article 31).</li><li>5. <input type="checkbox"/> A copy of the International Application as filed (35 U.S.C. 371(c)(2))<ol style="list-style-type: none"><li>a. <input type="checkbox"/> is attached hereto (required only if not communicated by the International Bureau).</li><li>b. <input type="checkbox"/> has been communicated by the International Bureau.</li><li>c. <input type="checkbox"/> is not required, as the application was filed in the United States Receiving Office (RO/US).</li></ol></li><li>6. <input checked="" type="checkbox"/> A English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).<ol style="list-style-type: none"><li>a. <input checked="" type="checkbox"/> is attached hereto.</li><li>b. <input type="checkbox"/> has been previously submitted under 35 U.S.C. 154(d)(4).</li></ol></li><li>7. <input type="checkbox"/> Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))<ol style="list-style-type: none"><li>a. <input type="checkbox"/> are attached hereto (required only if not communicated by the International Bureau).</li><li>b. <input type="checkbox"/> have been communicated by the International Bureau.</li><li>c. <input type="checkbox"/> have not been made; however, the time limit for making such amendments has NOT expired.</li><li>d. <input type="checkbox"/> have not been made and will not be made.</li></ol></li><li>8. <input type="checkbox"/> A English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).</li><li>9. <input type="checkbox"/> An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).</li><li>10. <input type="checkbox"/> A English language translation of the annexes of the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).</li></ol>		
Items 11 to 20 below concern other document(s) or information included:		
<ol style="list-style-type: none"><li>11. <input type="checkbox"/> An Information Disclosure Statement under 37 CFR 1.97 and 1.98.</li><li>12. <input type="checkbox"/> An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.</li><li>13. <input checked="" type="checkbox"/> A FIRST preliminary amendment.</li><li>14. <input type="checkbox"/> A SECOND or SUBSEQUENT preliminary amendment.</li><li>15. <input type="checkbox"/> A substitute specification.</li><li>16. <input type="checkbox"/> A change of power of attorney and/or address letter.</li><li>17. <input type="checkbox"/> A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821-1.825.</li><li>18. <input type="checkbox"/> A second copy of the published international application under 35 U.S.C. 154(d)(4).</li><li>19. <input type="checkbox"/> A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).</li><li>20. <input checked="" type="checkbox"/> Other items or information:<ul style="list-style-type: none"><li><input type="checkbox"/> Applicant claims small entity status.</li><li><input checked="" type="checkbox"/> Supplement to Transmittal Letter.</li></ul></li></ol>		

U.S. APPLICATION NO. (if known, see 37 CFR 1.5) <b>10/049690</b>	INTERNATIONAL APPLICATION NO. PCT/EP00/08084	ATTORNEY'S DOCKET NUMBER 825-161	
21. <input type="checkbox"/> The following fees are submitted:		<b>CALCULATIONS PTO USE ONLY</b>	
<b>Basic National Fee (37 CFR 1.492(a)(1)-(5)):</b>			
Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO.....		\$ 1,040.00	
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO.....		\$ 890.00	
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO .....		\$ 740.00	
International preliminary examination fee (37 CFR 1.482).paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4)..		\$ 710.00	
International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims satisfied provisions of PCT Article 33(1)-(4).....		\$ 100.00	
ENTER APPROPRIATE BASIC FEE AMOUNT =		\$890.00	
Surcharge of \$130.00 for furnishing the oath or declaration later than months from the earliest claimed priority date (37 C.F.R. 1.491(3)).		<input type="checkbox"/> 20 <input checked="" type="checkbox"/> 30 + 130.00	
CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE
Total Claims	10 - 20 =		x \$ 18.00
Independent Claims	1 - 3 =		x \$ 84.00
MULTIPLE DEPENDENT CLAIM(S) (if applicable)		+ \$280.00	
TOTAL OF ABOVE CALCULATIONS =		\$1020.00	
<input type="checkbox"/> Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by 1/2.		-	
SUBTOTAL =		\$1020.00	
Processing fee of \$130.00 for furnishing the English Translation later than months from the earliest claimed priority date (37 C.F.R. 1.492(f)).		<input type="checkbox"/> 20 <input type="checkbox"/> 30 +	
TOTAL NATIONAL FEE =		\$1020.00	
Fee for recording the enclosed assignment (37 C.F.R. 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 C.F.R. 3.28, 3.31). \$40.00 per property		+	
TOTAL FEES ENCLOSED =		\$1020.00	
		Amount to be refunded:	
		Charged:	
a. <input checked="" type="checkbox"/> A check in the amount of \$ 1020.00 to cover the above fees is enclosed. b. <input type="checkbox"/> Please charge my Deposit Account No. _____ in the amount of \$ _____ to cover the above fees. A duplicate copy of this sheet is enclosed. c. <input checked="" type="checkbox"/> The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 01.2000. A duplicate copy of this sheet is enclosed. d. <input type="checkbox"/> Fees are to be charged to a credit card. <b>WARNING:</b> Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.			
<b>NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.</b>			
SEND ALL CORRESPONDENCE TO: ANDRUS, SCEALES, STARKE & SAWALL, LLP 100 East Wisconsin Avenue, Suite 1100 Milwaukee, Wisconsin 53202 Phone: (414) 271-7590 Fax: (414) 271-5770			
 Signature		2-15-02 Date	
GARY A. ESSMANN Name		29,376 Reg. No.	

U.S. APPLICATION NO. (if known, see 37 CFR 1.5)	INTERNATIONAL APPLICATION NO.	ATTORNEY'S DOCKET NUMBER
<b>10/049690</b>	PCT/EP00/08084	825-161
CERTIFICATE OF EXPRESS MAIL		
I hereby certify that this correspondence is being deposited with the United States Postal Service with sufficient postage as EXPRESS MAIL-POST OFFICE TO ADDRESSEE, in an envelope addressed to: BOX PCT, COMMISSIONER OF PATENTS AND TRADEMARKS, WASHINGTON, D.C. 20231 on the <u>15th</u> day of February, 2002. Express Mail Label <u>EL 812734005 US</u> .		
GARY A. ESSMANN	29,376	
Name	Reg. No.	
	2-15-02	Date
Signature		

## IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Application of:

THOMAS TIEDEMANN and  
OTFRIED SCHWARZKOPF

- ) AXIAL PISTON DRIVE WITH A
- ) CONTINUOUSLY ADJUSTABLE
- ) PISTON STROKE
- )

**PRELIMINARY AMENDMENT**

Milwaukee, Wisconsin 53202

Box Patent Application  
Asst. Commissioner for Patents  
Washington, D.C. 20231

Sir:

Prior to computing the filing fee in this application, kindly amend the above identified application, as follows. The filing fee is to be computed on the amended claims.

**In the Specification:**

Beginning at page 1, between the title and the first line of text, the specification has been amended as follows:

**CROSS REFERENCE TO RELATED APPLICATION**

The present application is the U.S. national stage application of International Application PCT/EP00/08084, filed August 18, 2000, which international application was published on February 22, 2001 as International Publication WO 01/12989 A1 in the German language. The International Application claims priority of German Patent Application 199 39 131.9, filed August 18, 1999.

**In the Claims:**

Claim 1 has been amended as follows:

1. Axial piston drive with a continuously adjustable piston stroke, comprising a drive shaft (10, 12) on which a swash plate (16) is supported in a crank chamber (14) in such a way as to be tiltable and displaceable in the axial direction, and with a controller (18, 20) by means of which an tilt angle and an axial position of the

THOMAS TIEDEMANN and  
OTFRIED SCHWARZKOPF

Atty. Docket No. 825-161

swash plate (16) can be adjusted, and with at least one piston (26, 28) connected to the swash plate (16) so that it can be actuated to move within a cylinder (22, 24), wherein the controller (18, 20) incorporates an adjustment unit (30, 32) that is separated from the piston (26, 28) and hydraulically driven,

characterized in that the adjustment unit (30, 32) is supplied with compressed oil by a hydraulic unit that is independent of the medium being propelled by the piston (26, 28).

Cancel claim 2

Cancel claim 3

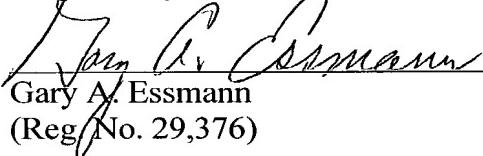
Add new claim 11 as follows:

11. Axial piston drive according to claim 1, characterized in that the adjustment unit (30, 32) is driven hydraulically.

Add new claim 12 as follows:

12. Axial piston drive according to claim 1, characterized in that the swash plate (16) is support on a joint head (48, 50) that can be axially displaced by means of a setting piston (44, 46) of the adjustment unit (30, 32) and the swash plate (16) is connected by an off-centre joint (52) to a component (54) that is fixed in the axial direction.

Respectfully submitted,

  
Gary A. Essmann  
(Reg. No. 29,376)

ANDRUS, SCEALES, STARKE & SAWALL, LLP  
100 East Wisconsin Avenue, Suite 1100  
Milwaukee, Wisconsin 53202  
(414) 271-7590  
Atty. Docket No. 825-161

THOMAS TIEDEMANN and  
OTFRIED SCHWARZKOPF

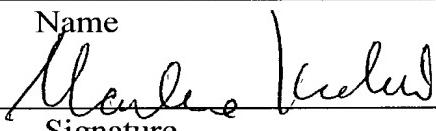
Atty. Docket No. 825-161

CERTIFICATE OF EXPRESS MAIL

I hereby certify that this correspondence is being deposited with the United States Postal Service, with sufficient postage, as EXPRESS MAIL - POST OFFICE ADDRESSEE, in an envelope addressed to: Commissioner for Patents, Washington, D.C. 20231 on the 15th day of February, 2002. The Express Label is EL812734005US.

Marlene Kubiak

Name



Signature

Reg. No.

February 15, 2002

Date

**VERSION WITH MARKINGS TO SHOW CHANGES MADE**

**Attorney Docket No. 825-161**

**In the specification:**

Please add the following paragraph at page 1, between the title and the first line of text as follows:

**CROSS REFERENCE TO RELATED APPLICATION**

The present application is the U.S. national stage application of International Application PCT/EP00/08084, filed August 18, 2000, which international application was published on February 22, 2001 as International Publication WO 01/12989 A1 in the German language. The International Application claims priority of German Patent Application 199 39 131.9, filed August 18, 1999.

**In the claims:**

Claim 1 has been amended as follows:

1. Axial piston drive with a continuously adjustable piston stroke, comprising a drive shaft (10, 12) on which a swash plate (16) is supported in a crank chamber (14) in such a way as to be tilttable and displaceable in the axial direction, and with a controller (18, 20) by means of which an tilt angle and an axial position of the swash plate (16) can be adjusted, and with at least one piston (26, 28) connected to the swash plate (16) so that it can be actuated to move within a cylinder (22, 24), characterized in that wherein the controller (18, 20) incorporates an adjustment unit (30, 32) that is separated from the piston (26, 28) and hydraulically driven,

characterized in that the adjustment unit (30, 32) is supplied with compressed oil by a hydraulic unit that is independent of the medium being propelled by the piston (26, 28).

Delete claim 2

Delete claim 3

Attorney Docket No. 825-161

Add new claim 11

11. Axial piston drive according to claim 1, characterized in that the adjustment unit (30, 32) is driven hydraulically.

Add new claim 12

12. Axial piston drive according to claim 1, characterized in that the swash plate (16) is support on a joint head (48, 50) that can be axially displaced by means of a setting piston (44, 46) of the adjustment unit (30, 32) and the swash plate (16) is connected by an off-centre joint (52) to a component (54) that is fixed in the axial direction.

(12) NACH DEM VERTRAG ÜBER DIE INTERNATIONALE ZUSAMMENARBEIT AUF DEM GEBIET DES  
PATENTWESENS (PCT) VERÖFFENTLICHTE INTERNATIONALE ANMELDUNG

(19) Weltorganisation für geistiges Eigentum  
Internationales Büro



(43) Internationales Veröffentlichungsdatum  
22. Februar 2001 (22.02.2001)

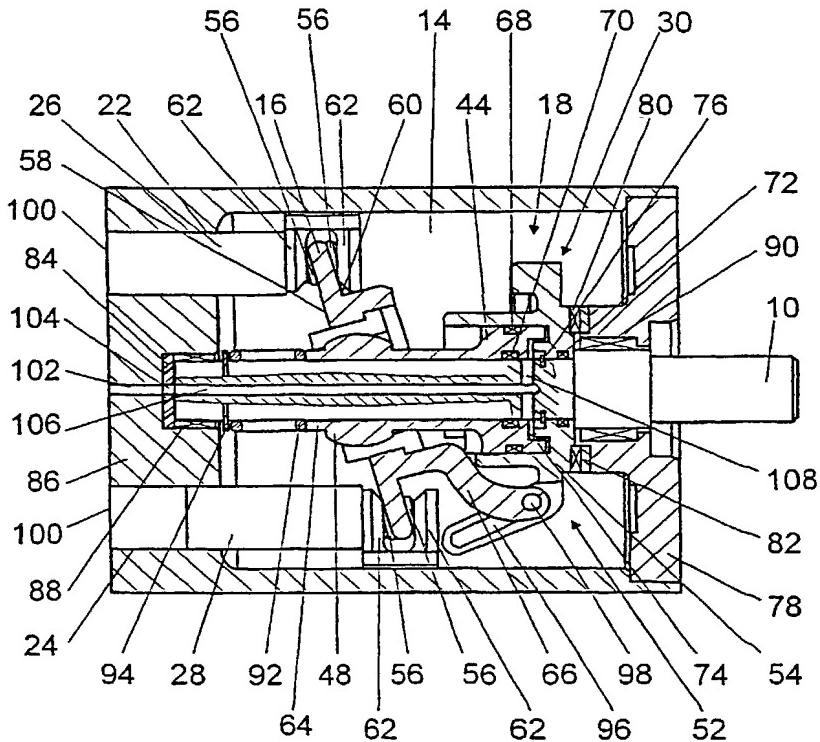
PCT

(10) Internationale Veröffentlichungsnummer  
**WO 01/12989 A1**

- |   |  |   |
|---|--|---|
| (51) Internationale Patentklassifikation <sup>7</sup> : | <b>F04B 27/18.</b>                           | (71) Anmelder (für alle Bestimmungsstaaten mit Ausnahme von US): <b>ZEXEL GMBH [DE/DE]</b> ; Zeppelinstrasse 5, 64331 Weiterstadt (DE).   |
| (21) Internationales Aktenzeichen:                      | PCT/EP00/08084                               | (72) Erfinder; und  |
| (22) Internationales Anmeldeatum:                       | 18. August 2000 (18.08.2000)                 | (75) Erfinder/Anmelder (nur für US): <b>TIEDEMANN THOMAS [DE/DE]</b> ; Friedrich-Engels-Strasse 28, 71636 Ludwigsburg (DE). <b>SCHWARZKOPF, Otfried [DE/DE]</b> ; Maichinger Strasse 10, 71106 Magstadt (DE). |
| (25) Einreichungssprache:                               | Deutsch                                      | (74) Anwälte: <b>POPP, Eugen usw.; Meissner, Bolte &amp; Partner</b> , Postfach 86 06 24, 81633 München (DE).   |
| (26) Veröffentlichungssprache:                          | Deutsch                                      | (81) Bestimmungsstaaten (national): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU,   |
| (30) Angaben zur Priorität:                             | 199 39 131.9 18. August 1999 (18.08.1999) DE | [Fortsetzung auf der nächsten Seite]  |

**(54) Title: AXIAL-PISTON DRIVE SYSTEM WITH A CONTINUOUSLY ADJUSTABLE PISTON STROKE**

**(54) Bezeichnung: AXIALKOLBENTRIEBWERK MIT EINEM STUFELOS VERSTELLBAREN KOLBENHUB**



**(57) Abstract:** The invention relates to an axial-piston drive system with a continuously adjustable piston stroke. The inventive drive system has a drive shaft (10, 12) on which a swash plate (16) is mounted in a crank chamber (14) in such a way that it is tiltable and axially displaceable. The drive system also comprises a control device (18, 20) by which means a tilting angle and an axial position of the swash plate (16) can be adjusted, and at least one piston (26, 28) which is connected to the swash plate (16) in a driving manner and can move in a cylinder (22, 24). According to the invention, said control device (18, 20) has an adjusting unit (30, 32) which is separate from the piston (26, 28).

**(57) Zusammenfassung:** Die Erfindung geht aus von einem Axialkolbentriebwerk mit einem stufenlos verstellbaren Kolbenhub, das eine Antriebswelle (10, 12) aufweist, auf der in einem Kurbelraum (14) eine Schrägscheibe (16) verkippbar und in axialer Richtung verschiebbar gelagert ist und

[Fortsetzung auf der nächsten Seite]

**WO 01/12989 A1**

3/Pts

5

Axial piston drive with a continuously adjustable piston stroke

## 10 State of the art

The invention relates to an axial piston drive with a continuously adjustable piston stroke according to the precharacterizing clause of Claim 1.

## 15 The use of axial piston drive with a continuously adjustable piston stroke is known in particular for motor-vehicle air conditioners, where they serve as coolant condensers.

The main components of an air conditioner for a motor vehicle are a coolant condenser, a first heat exchanger, the so-called evaporator, a second heat exchanger, an expansion organ and conduits that connect the components to one another. The role of the coolant condenser is to suck a coolant out of the evaporator, in which the coolant evaporates under heat absorption, and to condense it at a higher pressure level.

20 Subsequently, in the second heat exchanger, the coolant can release the heat at a higher temperature level, and in the expansion organ it is returned to a pressure level corresponding to that of the evaporator.

25 The output of the coolant condenser can be continuously adjusted by way of the speed of a drive motor and in an especially energetically favourable manner, in the case of axial piston drives, by way of the piston stroke. Known axial piston drives or axial piston condensers for vehicle air conditioners comprise a drive shaft operated by way of a

pulley. Within a crank chamber a swash plate is supported on the drive shaft so that it is unrotatably fixed and can be tilted by way of a joint. The swash plate drives at least one piston that can move within a cylinder. In order to absorb

5 tractive and pressure loads, each such piston is connected to the swash plate by way of two hinge yokes, one at the bearing surface of the swash plate that faces the piston and the other at the surface that faces away. With their flat surfaces contacting the bearing surfaces of the swash plate, the hinge  
10 yokes run at full circumferential velocity with a superimposed radial movement, which results in an elliptical path. The hinge yokes are seated with their rounded surfaces in sphere shaped formed bearings of the pistons, within which there is comparatively little relative movement during operation.

15 Furthermore, the connection between the the swash plate and the piston can be formed by way of a wobble plate rather than hinge yokes as described above. The wobble plate is secured against rotation with respect to the drive shaft by either a housing or  
20 piston rods. A bearing between the swash plate and the wobble plate absorbs the entire relative movement. The wobble plate performs only a wobbling movement as a result of the rotation of the swash plate.

The piston stroke and hence the output of the axial piston drive unit is adjusted by altering the tilt angle of the swash  
25 plate. A large tilt angle results in a long piston stroke and high output, whereas with a small tilt angle the piston stroke is shorter and the output lower. As a rule, the tilt angle of the swash plate is limited to a minimal and a maximal value by two stops. Ordinarily one or two guide pins are needed to guide  
30 the tilting movement in a specified manner and to avoid jamming. The tilt limiters, i.e. the stops, can be integrated into the guide pins.

If, as a result of adjustment of the tilt angle from a maximal value to a smaller one, a top-dead-centre point of the piston within the cylinder is shifted in the direction of the swash plate, already compressed gas cannot be completely expelled.

- 5 The compression energy introduced into the gas cannot be utilized for the cooling process. The result is a "damage space" between the piston and a valve plate on the cylinder, which causes a loss of energy. In order to avoid the damage space and to keep the top-dead-centre point of the piston in a  
10 constant position, the swash plate is supported so that it can additionally be axially displaced against a prestressed compression spring. The movement of the swash plate in the axial direction is usually limited by stops.

#### Advantages of the invention

- 15 The axial piston drive in accordance with the invention comprises a drive shaft with a swash plate supported thereon within a crank chamber so as to be tilttable and displaceable in the axial direction. A tilt angle and an axial position of the swash plate can be adjusted by a controller. The driving action  
20 of the swash plate is exerted by connection to at least one piston that can move within a cylinder.

It is proposed that the controller comprise an adjustment unit separate from the piston. With such a separate adjustment unit it is possible to obtain a large range of control that is  
25 independent of the operating points. A controlling torque can be applied exclusively in the direction of the possible adjustment movement of the swash plate, which enables jamming and increased wear and tear to be avoided.

- 30 Flow losses between the upper side of the piston and the crank chamber can also be avoided and the full output of the condenser can be exploited, for example for cooling an air

Translation of PCT/EP00/08084

- 4 -

conditioner. Moreover, the axial piston drive can be operated with low pressure in the crank chamber. A leakage flow of coolant from the crank chamber and outward through shaft seals is approximately proportional to the pressure in the crank 5 chamber. By keeping the pressure low, an elaborate sealing of the crank chamber can be eliminated and the leakage current made smaller. This is advantageous in particular in the case of coolants with high absolute pressures, for which in general high pressures in the crank chamber are needed to achieve 10 control by way of a gas-pressure difference at the piston. With a low pressure, furthermore, the coolant of an air conditioner is only slightly soluble in a lubricant of the condenser, as a result of which a high viscosity can be maintained.

Another way in which a separate adjustment unit has a positive 15 effect on viscosity is that heating of the lubricant by gas that has been warmed by the high-pressure side of the piston can be avoided. With a high viscosity, low friction between heavily loaded pairs of sliding elements on the swash plate and between the pistons and the cylinders can be achieved, which 20 contributes to a long working life and a high degree of reliability.

With an adjustment unit separate from the piston, no particular pressure in the crank chamber is needed for control, as a result of which coolant can be conducted from an evaporator 25 through the crank chamber into the cylinder. Therefore the crank chamber can be cooled, an additional suction chamber on the upper side of the piston can be avoided, and hence the whole structure occupies less space. Furthermore, it is usually possible to utilize a large volume of the crank chamber for the 30 attenuation of gas pulsations.

The adjustment unit can be driven electrically, pneumatically or preferably hydraulically. With hydraulic fluid an

advantageous damping of oscillation can be achieved and a particularly vibration-insensitive axial piston drive created. The hydraulic adjustment unit can be supplied with compressed oil by a hydraulic unit that is independent of the medium being 5 propelled by the piston; for example, a hydraulic unit that is already present in a motor vehicle can advantageously be used for this purpose. Additional components can then be eliminated and a large range of control, independent of the operating points of the axial piston drive, can be attained. Furthermore, 10 no build-up of pressure is needed for control when the axial piston drive is started up, for instance through a minimal tilt angle of 2°. A load-free starting of the axial piston drive is made possible, and it becomes easier to start devices such as an internal combustion engine that powers the axial piston 15 drive.

With an oil trap connected downstream of the condenser, good heat transfer into the heat exchanger can be ensured and a high efficiency of an air conditioner achieved. Furthermore, the oil trap can be put to particularly good use if it supplies the 20 hydraulic adjustment unit with compressed oil. Pressure is applied to the oil from the oil trap to an extent that depends on the operating point. If a large controlling torque is required, the pressure in the oil trap is high; if only a small controlling torque is needed, the pressure there is low.

25 In one embodiment it is proposed to connect the hydraulic adjustment unit to the crank chamber by way of a drain, which is a particularly useful arrangement in that the oil trap and the adjustment unit can be used to transport the lubricant back into the crank chamber. In this process, a influx from the oil 30 trap to the adjustment unit and/or the drain from the adjustment unit to the crank chamber can be made controllable. If only the drain or the influx is designed to be controllable,

whichever of these is not controlled can incorporate an inexpensive throttling site.

In the case in which only the drain or the influx can be controlled, it may happen that more lubricant is separated out in the oil separator than is needed for the adjustment unit or for the control. To ensure that the amount of lubricant in the crank chamber is always appropriate, in one embodiment it is proposed that there be disposed in the oil separator and/or in the crank chamber at least part of an oil-level controller which, when an oil level in the oil separator is exceeded and/or the oil in the crank chamber falls below a certain level, connects the oil separator to the crank chamber by way of a channel. It is further possible for the oil separator to be permanently connected to the crank chamber by a channel and a throttling site, or the oil separator and the amount of oil coordinate with respect to one another in such a way that the oil separator overflows before an oil or lubricant deficiency develops in the crank chamber. The overflowing oil can subsequently be sent into the crank chamber, for example together with a coolant for an air conditioner. With a controlled influx and a controlled drain, it can be ensured that the crank chamber always contains an adequate amount of lubricant.

The swash plate can be constructed so as to be tilttable and axially displaceable in various ways, as seems appropriate to a person skilled in the art. For example, the swash plate can be supported on a Z shaft with a tilted bore of bearing, and a stroke movement can be superimposed by a rotational movement of the bearing disk, and so on. In one embodiment of the invention it is proposed that the swash plate be supported on a joint head that can be axially displaced by means of a setting piston incorporated in the adjustment unit, and that the swash plate also be connected by way of an off-centre joint to a component

that is fixed in the axial direction. A structurally simpler and more economical displacement mechanism can thus be achieved, in which the tilt angle and axial position of the swash plate are related to one another in a specified manner.

- 5 The top-dead-centre point of the piston within the cylinder can be maintained and it becomes possible to avoid a damage space and energy losses, as a result of which the axial piston drive can be used particularly advantageously as a condenser in an air conditioner. The condenser can be designed as a pure swash-  
10 plate condenser or as a wobble-plate condenser. Furthermore, the solution in accordance with the invention can be employed with gear mechanisms and the like.

It is advantageous to construct the setting piston and the joint head in one piece, which can provide a saving in extra  
15 components as well as the effort of assembly and expense. The adjustment unit can be so disposed that it either rotates with the drive shaft, partially or completely, or is unrotatably fixed within a housing. Furthermore, the adjustment unit can act on the swash plate either from the side away from the  
20 piston or from the side facing the piston.

#### Drawing

Additional advantages will be apparent from the following description of drawings that show exemplary embodiments of the invention. The drawings, the description and the claims contain  
25 numerous characteristics in combination. A person skilled in the art will be able also to consider the characteristics individually and to assemble them into other useful combinations.

The individual figures show the following:

Fig. 1 an axial piston drive with the piston at the maximal end of its stroke, in section,

Fig. 2 an axial piston drive with the piston at the minimal end of its stroke, in section,

5 Fig. 3 part of a variant according to Fig. 1, and

Fig. 4 a schematic diagram of a form of hydraulic control.

#### Description of the exemplary embodiments

Fig. 1 shows an axial piston drive for an air conditioner of a  
10 motor vehicle, which operates as a condenser. The axial piston  
drive comprises a drive shaft 10 on which a swash plate 16 is  
supported within a crank chamber 14. The driving action of the  
swash plate 16 is exerted by way of hemispherical hinge yokes  
15 56, which connect it to pistons 26, 28 that are guided within  
cylinders 22, 24. To absorb tractive and pressure loads, each  
piston 26, 28 is connected to the swash plate 16 by way of two  
hinge yokes 56, one of which contacts the bearing face 58 that  
faces away from the pistons 26, 28 while the other contacts the  
bearing Face 60 that faces towards the pistons 26, 28. The  
20 hinge yokes 56 run, by way of their flat surfaces, along the  
bearing faces 58, 60 of the swash plate 16 at the full  
circumferential velocity with superimposed radial movement, as  
a result of which an elliptical track is produced. The rounded  
surfaces of the hinge yokes 56 are seated in sphere shaped  
25 formed bearings 62 of the pistons 26, 28, within which there is  
comparatively little relative movement during operation.

The swash plate is connected to the drive shaft 10 in a  
unrotatably fixed manner, by way of a joint head 48 of a sleeve  
64. So that the piston stroke and hence the output of the axial

piston drive can be continuously adjusted, the swash plate 16 is made so that it can be tilted on the joint head 48 by means of a controller 18 and moved in the axial direction along with the sleeve 64. When the tilt angle is large, a long piston  
5 stroke and a high output are achieved, while with a small tilt angle the piston stroke is short and the output low (Figs. 1 and 2).

In accordance with the invention the controller 18 comprises a hydraulic adjustment unit 30 that is separate from the pistons  
10 26, 28. The adjustment unit 30 incorporates a setting piston 44 formed in one piece with the sleeve 64 and the joint head 48. The setting piston 44 is guided within a cylinder formed by an adjustor housing 54. The adjustor housing 54 is attached to the drive shaft 10 in a form-fitting manner, in the radial  
15 direction by way of a fitting means not shown here, and axially by way of a tension ring 76. The drive shaft 10 is axially supported in the direction away from the cylinders 22, 24 by the adjustor housing 54, an axial bearing 80 and a running plate 82 set into a cover 78; in the direction towards the  
20 cylinders 22, 24 it rests against a housing 86 of the axial piston drive by way of an axial slide bearing 84. The drive shaft 10 is additionally supported in the cover 78 and in the housing 86 by way of two radial bearings 88, 90.

The positioning piston 44, together with the cylinder, encloses  
25 a pressure space 74 that is sealed off by three seals 68, 70, 72. The swash plate 16 is connected to the adjustor housing 54 by way of a joining element 66, which is formed integrally with the swash plate 16, and by an off-centre joint 52.

When compressed oil enters the pressure space 74, the  
30 positioning piston 44 is displaced, together with the sleeve 64, the joint head 48 and the swash plate 16, in the direction towards the cylinders 22, 24, against a prestressed pressure

spring 92 (Fig. 2). The pressure spring 92 is nonrotatably attached to the drive shaft 10 and is braced against a tension ring 94 in the direction away from the setting piston 44. By the off-centre joint 52, formed by a bolt 98 that is fixed to 5 the joining element 66 and is guided within a slot 96, the stroke movement of the swash plate 16 causes a moment of tilt acting on the swash plate 16. Upon the stroke movement of the swash plate 16 is superimposed a tilting movement, guided by the bolt 98 in the slot 96, so that in all cases a top-dead- 10 centre point 100 of the piston 26, 28 within the cylinders 22, 24 is preserved. So that only a small amount of oil is required, the volume of the pressure space 74 is preferably small.

The adjustment unit 30, specifically the setting piston 44, is 15 supplied with compressed oil from an oil separator disposed downstream of the cylinders 22, 24, by way of an axial bore 102, 104, 106 in the housing 86, in the slide bearing 84 and in the drive shaft 10, and by way of a radial bore 108 in the drive shaft 10 (Figs. 1, 2 and 4). The compressed oil is 20 advantageously fed into the drive shaft 10 axially, in the middle. In this region the relative movement between the drive shaft 10 and the slide bearing 84 is advantageously made small. Furthermore, the slide bearing 84 can additionally be used as a seal. If no oil pressure has yet developed in the oil separator 25 34 when the mechanism is first started, the pressure spring 92 sets the tilt angle to maximal, which ensures a build-up of pressure.

The adjustment unit 30 is connected to the oil separator 34 by a influx 38 and to the crank chamber 14 by a drain 36. The 30 influx 38 and drain 36 can each be controlled by a valve 110, 112. If a higher controlling torque is needed, the valve 110 opens. The oil flows at a higher pressure level into the adjustment unit 30 and acts on the setting piston 44. The valve

112 remains closed during this process. If a smaller controlling torque is needed, the valve 112 opens, allowing the oil to flow out of the adjustment unit 30 and making less force available in the adjustment unit 30. The swash plate 16 is  
5 displaced by the pressure spring 92 in the direction towards the maximal tilt angle. The valve 110 is closed.

If one of the valves 110, 112 is replaced by a throttle, so that only the influx 38 or the drain 36 can be controlled, there can advantageously be provided an oil-level controller 40  
10 and a channel 42 from the oil separator 34 to the crank space 14, as indicated in Fig. 4, to ensure that an adequate amount of lubricant is always available in the crank space 14.

Figure 3 shows part of a variant of an axial piston drive with a controller 20. Components that are substantially the same are  
15 in general identified by the same reference numerals. Regarding the function and components not shown here, reference is made to the exemplary embodiment in Figs. 1 and 2. The controller 20 comprises an adjustment unit 32 with a setting piston 46 that is nonrotatably disposed in an annular recess 122 in a housing  
20 114 of the axial piston drive. This arrangement makes an additional adjustor housing unnecessary. The positioning piston 46 is loaded in the direction towards the swash plate 16 by a first compression spring 136, is sealed off from the housing  
114 by two seals 116, 118 and acts on the swash plate 16 in the  
25 axial direction, by way of a sleeve 120 and a joint head 50 formed integrally with the sleeve 120, against a second prestressed, stronger pressure spring 124. In the direction away from the setting piston 46 the spring 124 is braced against a shoulder 126 of a drive shaft 12. The swash plate 16  
30 is braced in the axial direction by an off-centre joint (not shown here), so that the stroke movement of the swash plate 16 exerts a moment of tilt on the swash plate 16. The setting piston 46 and the sleeve 120 are connected to one another by an

axial bearing 128 that acts on both sides, such that the positioning piston 46 forms inner bearing faces whereas the sleeve 120 and a fastening element 130 form outer bearing faces. With the fastening element 130, which is connected to  
5 the sleeve 120 by a screw thread 132, the degree of axial play in the axial bearing 128 can be set to a specified value. The adjustment unit 32, i.e. the setting piston 46, is supplied with compressed oil from an oil separator 34 by way of an axial bore 134, as is the adjustment unit 30 (cf. relevant part of  
10 Fig. 4).

List of reference numerals

10	Drive shaft	74	Pressure space	
12	Drive shaft	76	Tension ring	
14	Crank space	78	Cover	
5	16	Swash plate	Axial bearing	
18	Controller	82	Thrust washers	
20	Controller	84	Slide bearing	
22	Cylinder	86	Housing	
24	Cylinder	88	Bearing	
10	26	Piston	Bearing	
28	Piston	92	Pressure spring	
30	Adjustment unit	94	Tension ring	
32	Adjustment unit	96	Slot	
34	Oil spearator	98	Bolt	
15	36	Drain	100	Top-dead-centre
38	Influx	102	Bore	
40	Oil-level controller	104	Bore	
42	Channel	106	Bore	
44	Setting piston	108	Bore	
20	46	Setting piston	110	Valve
48	Joint head	112	Valve	
50	Joint head	114	Housing	
52	Joint	116	Seal	
54	Component	118	Seal	
25	56	Hinge yoke	120	Joint sleeve
58	Bearing face	122	Recess	
60	Bearing face	124	Pressure spring	
62	Bearing	126	Shoulder	
64	Joint sleeve	128	Bearing	
30	66	Joining element	130	Fastening element
68	Seal	132	Screw thread	
70	Seal	134	Bore	
72	Seal	136	Pressure spring	

5

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15 Claims

1. Axial piston drive with a continuously adjustable piston stroke, comprising a drive shaft (10, 12) on which a swash plate (16) is supported in a crank chamber (14) in such a way  
20 as to be tilttable and displaceable in the axial direction, and with a controller (18, 20) by means of which an tilt angle and an axial position of the swash plate (16) can be adjusted, and with at least one piston (26, 28) connected to the swash plate (16) so that it can be actuated to move within a cylinder (22,  
25 24), characterized in that the controller (18, 20) incorporates an adjustment unit (30, 32) separated from the piston (26, 28).

2. Axial piston drive according to Claim 1, characterized in that the adjustment unit (30, 32) is driven hydraulically.

30 3. Axial piston drive according to Claim 2, characterized in that the adjustment unit (30, 32) is supplied with compressed oil by a hydraulic unit that is independent of the medium being propelled by the piston (26, 28).

4. Axial piston drive according to Claim 2, characterized in that the hydraulic adjustment unit (30, 32) is supplied with compressed oil by an oil separator (34) disposed downstream of the cylinder (22, 24).

5 5. Axial piston drive according to Claim 4, characterized in that the adjustment unit (30, 32) is connected to the crank chamber (14) by way of a drain (36), and a influx (38) from the oil separator (34) to the adjustment unit (30, 32) or the drain (36) from the adjustment unit (30, 32) to the crank chamber 10 (14) can be controlled.

6. Axial piston drive according to Claim 5, characterized in that in the oil separator (34) and/or in the crank chamber (14) at least part of an oil-level controller (40) is disposed which, when a specified oil level in the oil separator (34) is exceeded and/or when the oil in the crank chamber (14) falls below a certain level, connects the oil separator (34) to the 15 crank chamber (14) by way of a channel (42).

7. Axial piston drive according to Claim 5, characterized in that in the oil separator and an amount of oil that is present 20 are matched to one another in such a way that before an oil deficiency appears in the crank chamber (14), the oil separator overflows and the overflowing oil flows back into the crank chamber (14).

8. Axial piston drive according to Claim 4, characterized in 25 that in the adjustment unit (30, 32) is connected to the crank chamber (14) by way of a drain (36), and a influx (38) from the oil separator (34) to the adjustment unit (30, 32) and the drain (36) from the adjustment unit (30, 32) to the crank chamber (14) can be controlled.

9. Axial piston drive according to one of the preceding claims, characterized in that the swash plate (16) is supported on a joint head (48, 50) that can be axially displaced by means of a setting piston (44, 46) of the adjustment unit (30, 32)
- 5 and the swash plate (16) is connected by an off-centre joint (52) to a component (54) that is fixed in the axial direction.
10. Axial piston drive according to Claim 9, characterized in that in the setting piston (44) and the joint head (48) are constructed in one piece.

Axial piston drive with a continuously adjustable piston stroke

5

Abstract

The invention relates to an axial piston drive with a continuously adjustable piston stroke, which comprises a drive shaft (10, 12) on which a swash plate (16) is supported in a crank chamber (14) in such a way as to be tilttable and displaceable in the axial direction, as well as a controller (18, 20) by means of which an tilt angle and an axial position of the swash plate (16) can be adjusted, and at least one piston (26, 28) connected to the swash plate (16) so that it can be actuated to move within a cylinder (22, 24).

It is proposed that the controller (18, 20) incorporates an adjustment unit (30, 32) separated from the piston (26, 28).

(Fig. 1)

1 / 3

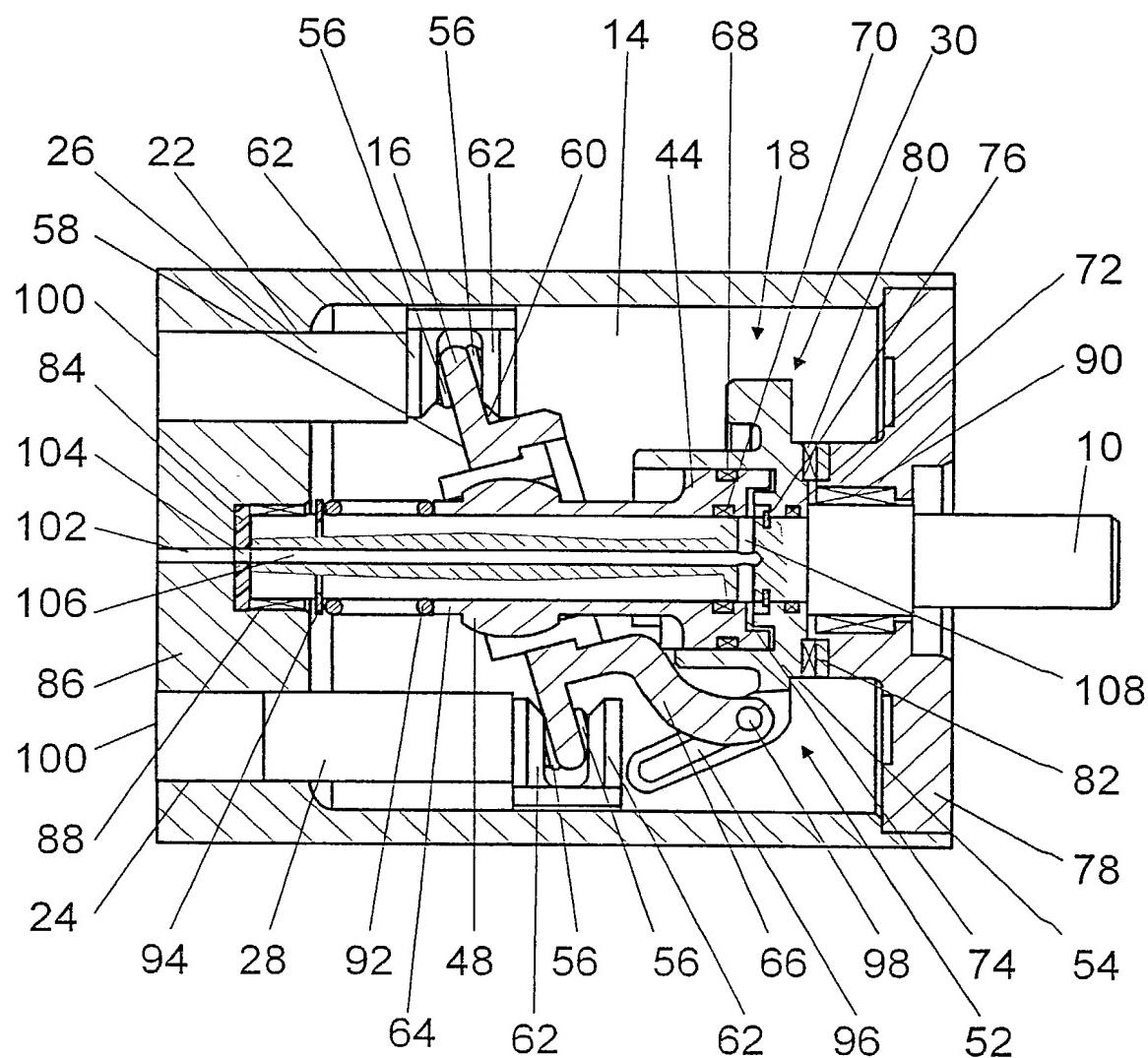


Fig. 1

2 / 3

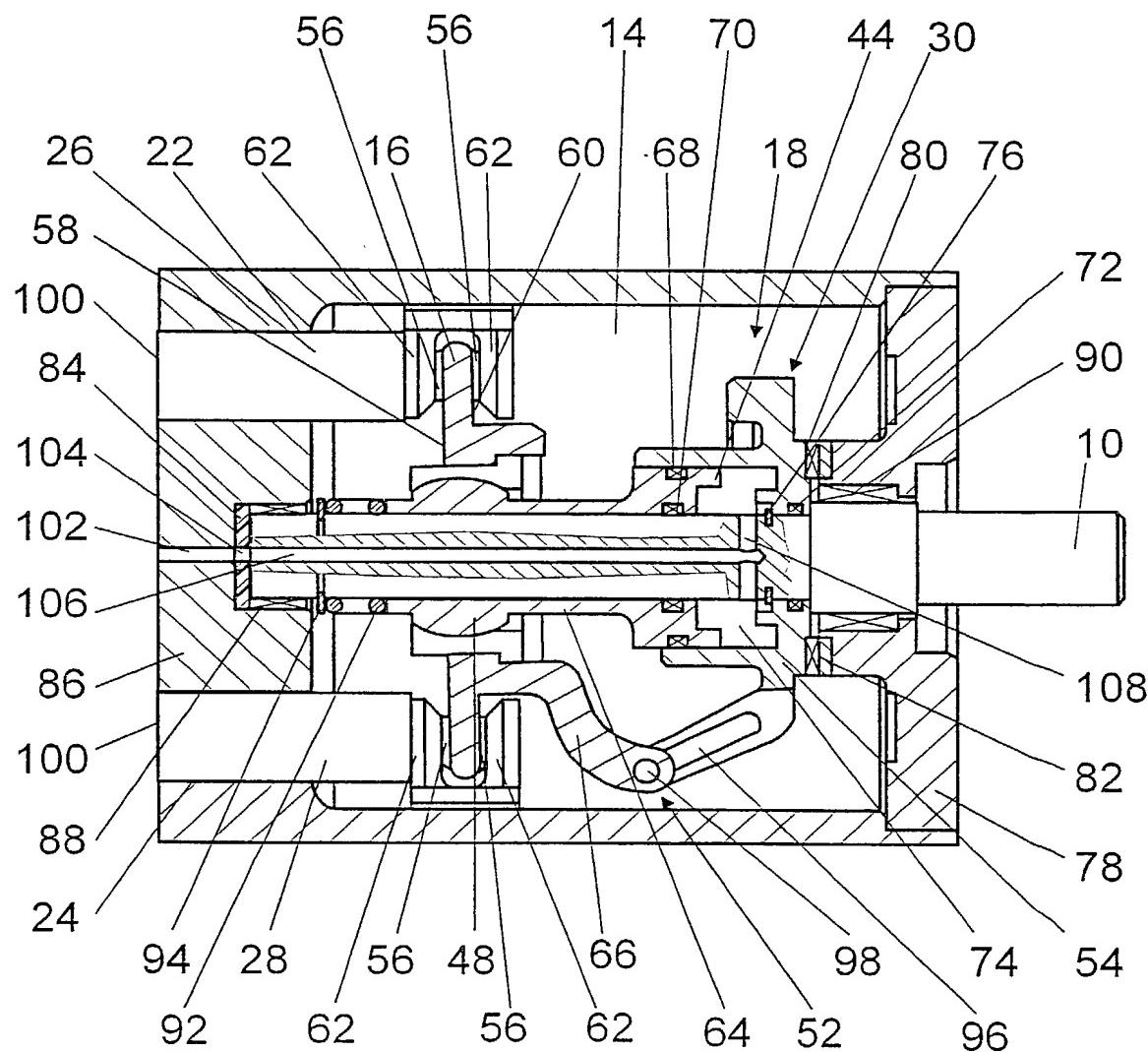


Fig. 2

3 / 3

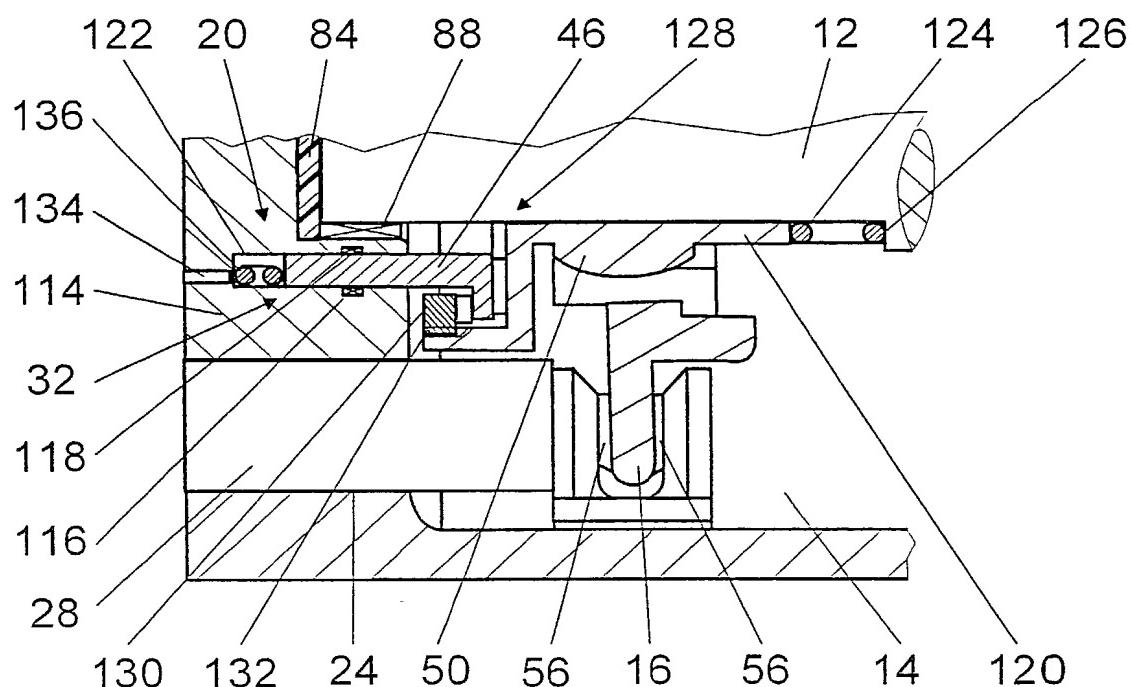


Fig. 3

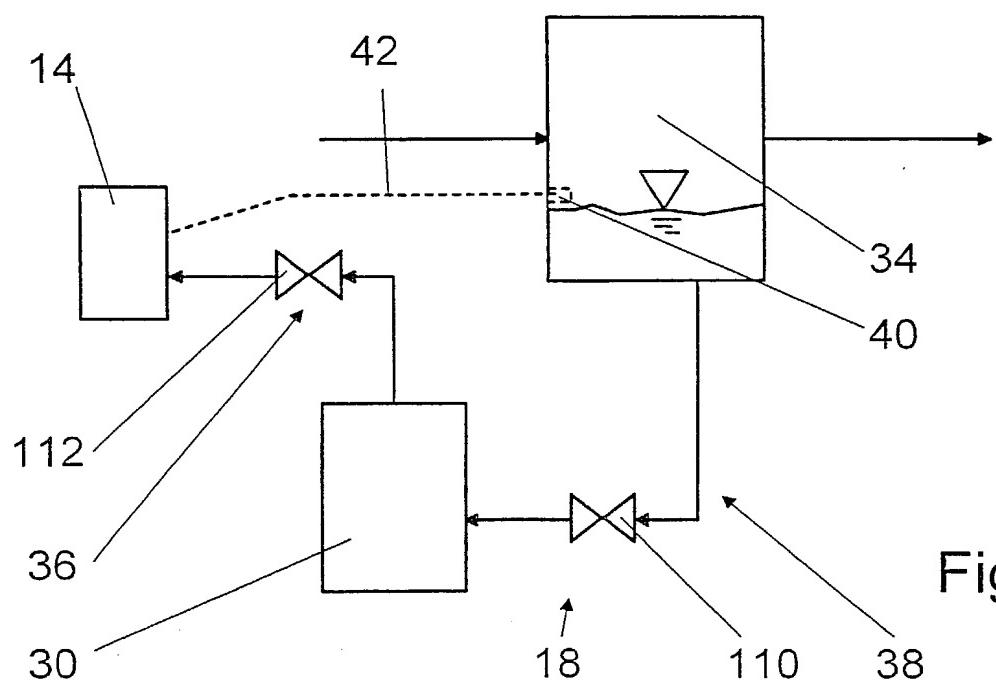


Fig. 4

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PTO/SB/01 (8/96)		DECLARATION	Attorney Docket Number	825-161
		Declaration <input type="checkbox"/> Submitted with Initial Filing	First-Named Inventor	Thomas Tiedemann
		<input checked="" type="checkbox"/> Submitted after Initial Filing	COMPLETE IF KNOWN	
			Application Number	
			Filing Date	
			Group Art Unit	
			Examiner Name	

As a below named inventor, I hereby declare that:

My residence, post office address, and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

## AXIAL PISTON DRIVE WITH A CONTINUOUSLY ADJUSTABLE PISTON STROKE

(Title of the Invention)

the specification of which  
 is attached hereto

OR

was filed on (MM/DD/YYYY) [REDACTED] as United States Application Number or PCT

International Number [REDACTED] PCT/EP00/08084 and was amended on (MM/DD/YYYY) [REDACTED]  
(if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment specifically referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in Title 35 Code of Federal Regulations, §1.56.

I hereby claim foreign priority benefits under Title 35, United States Code §119(a)-(d) or §365(b) of any foreign application(s) for patent or inventor's certificate, or §365(a) of any PCT International application which designated at least one country other than the United States of America, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or of any PCT International application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application Number(s)	Country	Foreign Filing Date (MM/DD/YYYY)	Priority Not Claimed	Copy Attached?
				YES NO
199 39 131.9	Germany	08/18/1999	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>

Additional foreign application numbers are listed on a supplemental priority sheet attached hereto.

I hereby claim the benefit under Title 35, United States Code §119(e) of any United States provisional application(s) listed below.

Application Number(s)	Filing Date (MM/DD/YYYY)	Additional provisional application numbers are listed on a supplemental priority sheet attached hereto.
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### DECLARATION

I hereby claim the benefit under Title 35, United States Code §120 of any United States application(s), or §365(e) of any international application designated the United States of America, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of Title 35, United States Code §112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations §1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application.

U.S. Parent Application Number	PCT Parent Number	Parent Filing Date (MM/DD/YYYY)	Parent Patent Number (if applicable)

Additional U.S. or PCT international application numbers are listed on a supplemental priority sheet attached hereto.

As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith:

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under §1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued therefrom.

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